22 WAYS TO OPTIMIZE HIGH TUNNEL PRODUCTION

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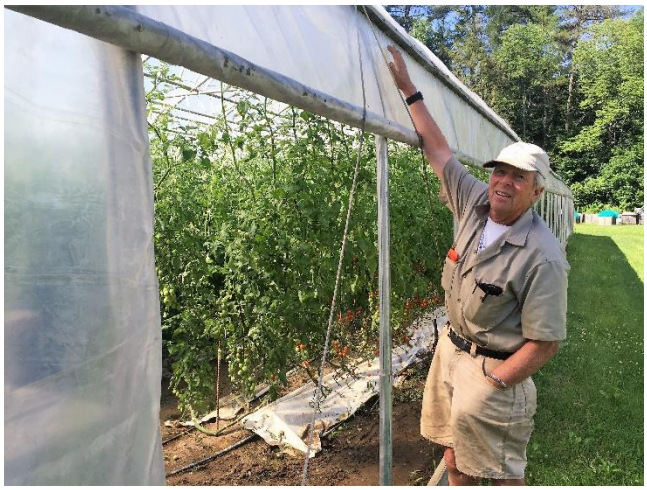
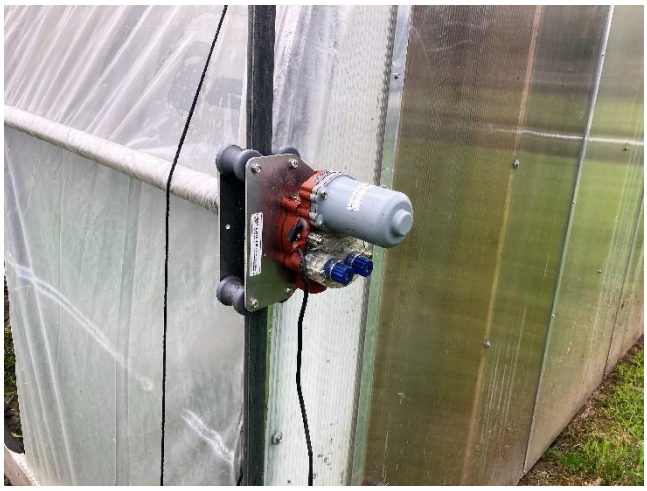
High tunnel systems vary a lot – from super simple to all the bells and whistles – depending on grower goals, crops, finances, etc. so it's hard to make one list of improvements that fits everyone's situation. Maybe you've done all these things, or maybe you don't need to. Hopefully there's something in the list below that's helpful to your high tunnel management!

1. **Replace greenhouse plastic before it's too old**. Most greenhouse plastic is rated for 4 years of use. Although they may hold up longer than that physically, all plastic films lose light transmission capabilities over time. Even with UV stabilizers that slow degradation, dust, dirt, and air pollutant accumulation can reduce light available to crops for photosynthesis. Tests of UV-stabilized plastic covering on a multi-bay greenhouse revealed a 6.8% reduction in transmission in Photosynthetically Active Radiation (PAR) after 4 years. Using a PAR meter, or quantum sensor, I have observed this on farms myself. The difference in PAR transmission between old and new covers is more important to crop growth when sunlight is limited, as it is early in the season, or on cloudy days.

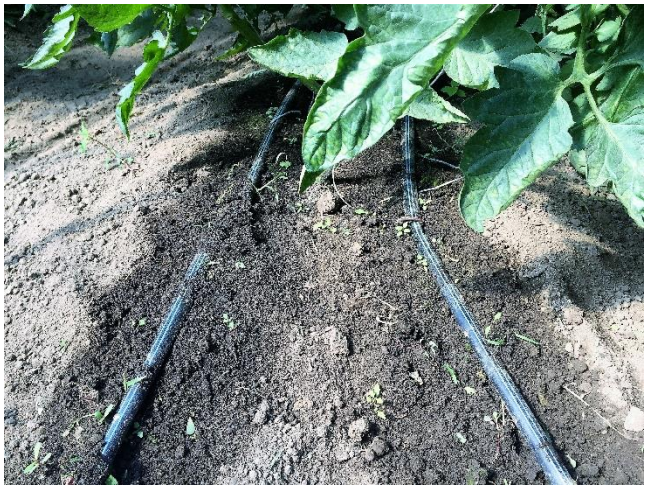
2. **Add ground post extensions** to increase height of short tunnels. Many older tunnels were shorter than the norm today, so they have small interior volumes and short sidewall openings that limit passive ventilation. When replacing plastic, consider adding sidewall extensions to raise the height of the structure, which will reduce temperature fluctuations by increasing the volume of air. This also improves ventilation and lowers humidity more when bigger sidewalls are fully open. Depending on tunnel design it can also allow for growing taller crops and make room for workers to stand up next to tunnel edges. Cross braces or other structural improvements may be needed to ensure tunnel stability after ground post extensions are added.



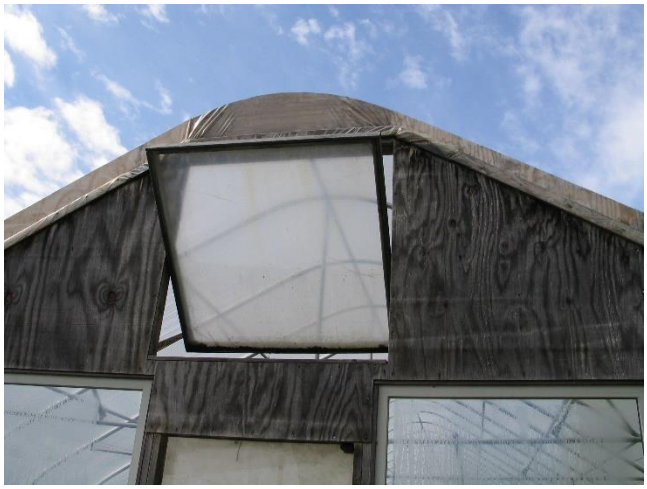
3. **Optimize roll up sides**. Back in the day, a piece of pipe was how most sidewall plastic was rolled up. Today, there are many easier, and safer methods available that use geared systems powered by hand or electricity. There are also automated systems that use sensors to raise and lower the sidewalls depending on environmental conditions. These are not inexpensive but growers I've talked to say they help optimize crop growing conditions by avoiding exposure to hot/cold temperatures when someone is not available to change the sidewall opening, and they offer some peace of mind if you're away from the farm when the weather changes significantly.



4. **Add drip lines if needed** to wet the entire root zone. The extent to which irrigation water moves sideways in soil after it is applied depends on capillary movement. Capillary movement is enhanced by clay and organic matter content of soil. So if your soil is on the sandy side then there may be large dry areas between your irrigation lines if they are widely spaced. That can limit root growth and prevent plants from taking up nutrients even though they were applied. Adding extra drip lines is a low-cost way to make sure that water is distributed uniformly across the entire tunnel growing area. Set up irrigation timers, even inexpensive ones can help provide a consistent water supply.

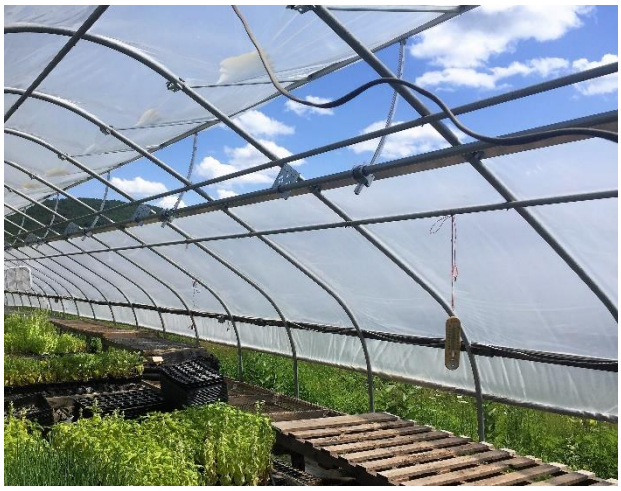


5. **Improve ventilation**: add a ridge vent or install hinged gable vents in endwalls. Good ventilation not only provides a consistent supply of fresh air and thus CO2 for plant growth, it's also critical to managing humidity which can shut down photosynthesis if it's too high, as well as promote foliar plant diseases. Ridge vents are very effective and promoting air flow and ventilation in high tunnels, though they are not inexpensive, and I hear growers complain about changing the plastic with them. A lower cost alternative, albeit with less impact on air flow, is to install large openings near the top of tunnel endwalls, or gable vents. These can be hinged to open inward, or in "butterfly" fashion. Outward openings are more susceptible to wind damage. Typically, rope and pulley systems are used to operate gable vents.



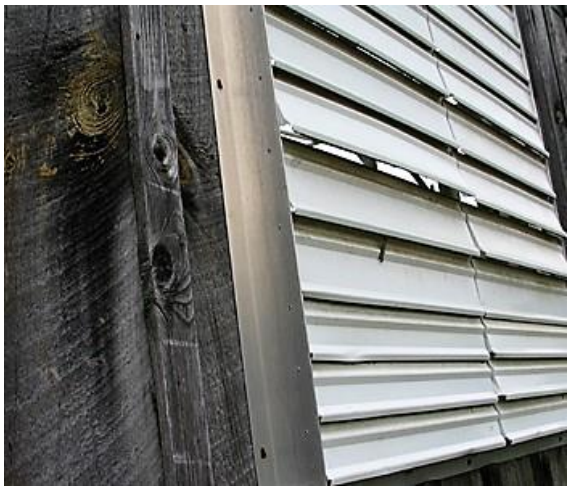
6. **Improve air circulation** with HAF fans. Air circulation is not the same as ventilation. Circulation mixes internal air, reducing gradients in temperature, humidity, and CO2 that may be present. Ventilation without circulation can lead to corners or other areas of a tunnel not having sufficient air exchange. Properly installed horizontal air flow fans are a good investment in many high tunnels. Small, 1/10 to 1/15 hp HAF fans with permanent split capacitor motors work well. They move more air yet use less electricity than cheap box fans with shaded pole motors that are often seen in high tunnels.

7. **Size ventilation and circulation systems properly**. Ventilation flow rates are expressed as cubic feet per minute per square foot of growing area. Good mechanical ventilation requires the right size fans and/or openings. With passive ventilation it's just openings. An old article by John Bartok, former UConn Extension Ag Engineer, states that roof vent areas should equal the combined sidewall vent area, and each should be at least 15% of the floor area. That seems like a lot, and it suggests that many high tunnels have insufficient passive ventilation. Guidance for circulation flow rates is 25% of the overall growing volume per minute. See Chris Callahan's blog post on greenhouse ventilation for summary of how to size these systems.

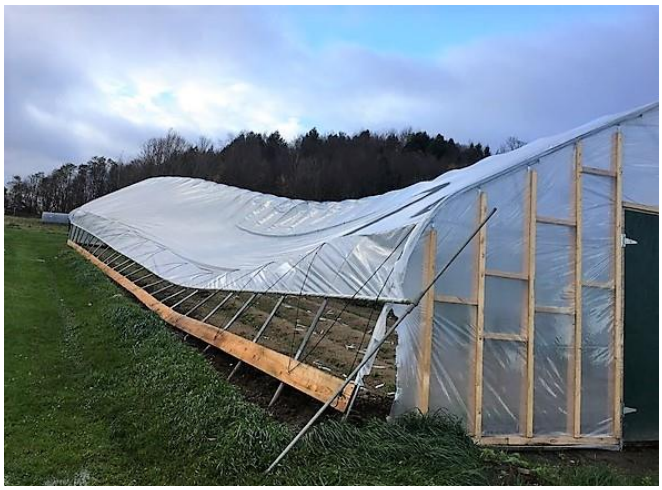


8. **Have furnaces professionally serviced** before the heating season. Quoting John Bartok once again: "Keeping the greenhouse heating system in good repair and operating condition can save money in several ways. Fuel consumed may be reduced as much as 20 percent. Heat distribution may be more uniform resulting in a lower thermostat setting and better plant growth. The system is less likely to fail causing crop losses." Servicing furnaces is important to prevent ethylene damage that can result from cracked heat exhangers or improper combustion gas exhaust. Here's a checklist for heating system maintenance.

9. **Seal gaps to avoid heat loss**. Whether you heat a high tunnel with solar energy alone or with supplemental heat, avoiding heat loss at night and on cold days is a good thing. I've seen many tunnels with gaps around doors and roll up sides, and louvers that don't seal. Some growers use old drip tape or used bicycle tire tubing as weatherstripping in door frames. Some brands of ventilation louvers work better than others (see Chris Callahan's blog post, above). And it's standard to have an extra panel of plastic cover left in place that overlaps with each end of the roll-up side, to create a better seal at the corners of a tunnel.



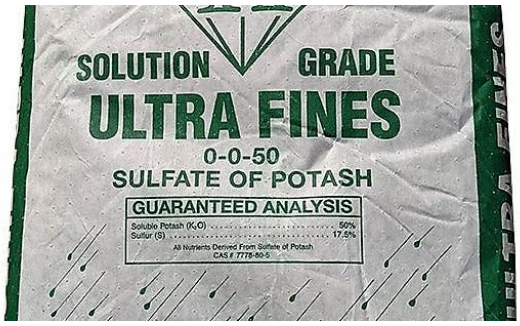
10. **Prepare for climate extremes**. The weather is getting whackier. Large, sometimes rapid, fluctuations in temperature and precipitation make tunnel growing more and more attractive compared to the field, but tunnels are not immune from extreme weather impacts. Options for coping include perimeter drainage, perimeter insulation, shade cloth, shade spray or paint. And don't forget to plan for worst case winds and heavy snow load to avoid collapse of tunnel structures.



11. **Thoroughly mix soil to re-distribute salts** that have moved up to the surface. A SARE-funded research project conducted by UMaine, UNH and UVM found that during winter months, high tunnel soil can became strongly stratified in terms of soluble salt levels. In two test sites, there was a 10-fold difference in soluble salts between measurements from the top inch of soil vs. a sample 2-3 inches deep. This has implications in terms of soil sampling and seed germination. Although no-till has many upsides, it may not be appropriate in tunnels. Mix your tunnel soil well before testing it or sowing crops.

12. **Soil test**, well in advance of planting seeds and transplants. For in-ground vegetable production we recommend the use of both the saturated media extract (SME) and the regular field soil test (modified Morgan's extract) to assess the levels of soluble and reserve nutrients, respectively. The UMaine Testing lab offers a "combined high tunnel package" for $30 that includes both tests. SME also measures soluble salts and soluble forms of nitrogen.
The SME was developed as a potting soil test, it should be used to test your potting soil mixes well in advance of planting to avoid problems. The cost is $18 at UMaine, and many other labs also offer this test. Leaf sampling for long-season crops like tomato is the best way to know what the plants actually take up from the soil. Cost is $27 per sample from DairyOne and other labs.

13. **Apply plenty of K** but avoid fertilizers with large granules. The study cited above found that 500-600 lbs./acre of applied K minimized yellow shoulder and maximized yields of high tunnel tomatoes. Potassium sulfate, a common tunnel fertilizer, varies widely in particle size, and this affects solubility and release rate. When fertilizer with very large particles (several mm diameter) was applied, some large particles were still intact 2 years after application. These would not be available for plant uptake despite being measured by soil tests. When incorporating fertilizers like potassium sulfate, it is advisable to use "fines" that are formulated for more rapid solubility.



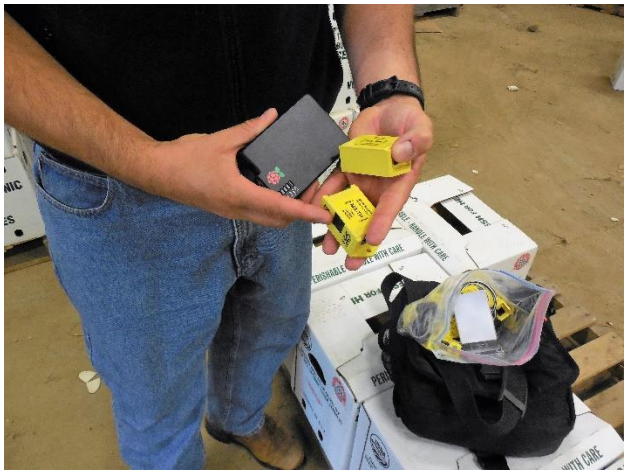
14. **Test your irrigation water**. In the high tunnel, irrigation is the only source of water whereas for crops grown outside, irrigation water is diluted by rainfall. It makes sense to test your tunnel irrigation water to optimize yields and to avoid potential toxicity issues. Penn State's guidance advises testing water for pH, alkalinity, conductivity, hardness, chloride, and sodium at a minimum. Their lab offers irrigation water tests starting at $35. Their fact sheet shows the ranges found in over 400 water tests submitted, which provides some idea of the variation out there. If you water has high alkalinity, this UMass fact sheet offers management guidance.

15. **Evaluate and possibly adjust planting density**. High density plantings can increase yield, as Becky Maden's on-farm research with high tunnel tomatoes has shown. Highest yielding tunnels typically had 4 sq. ft. or less per tomato leader. Similarly, packing leafy greens into tunnels, even eliminating walkways, can also increase yield. Of course, high densities reduce air movement and may increase foliar disease, thus the importance of air ventilation and circulation.

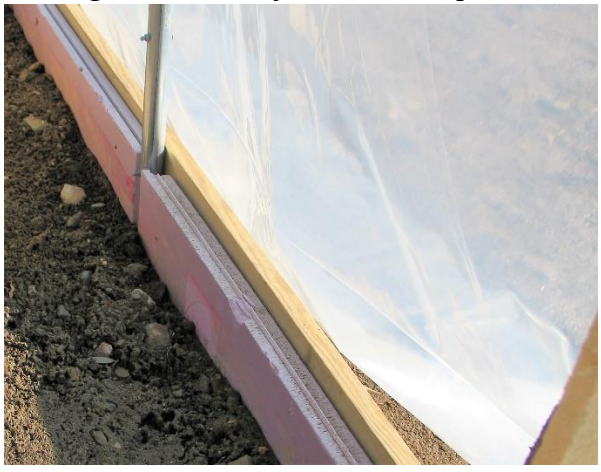
16. **Use "guardian plants"** as part of your IPM program. Guardian plants help protect plants by supporting biological control agents that kill pests. For example, marigolds can be used to manage western flower thrips in combination with predatory mites and a granular form of a commercially available insect-killing fungus to create a self-sustaining IPM system. The UVM Entomology Lab offer this do-it-yourself guide. If you've ever had thrips in your tunnels, you know they can be difficult to control.

17. **Establish a pest monitoring and scouting program**. Using traps and inspecting plants on a regular basis can keep pest problems from becoming unmanageable. Consider assigning one person to be your "IPM scout" performing a weekly walk-through of all tunnels, documenting insect and disease populations, and taking pictures of any symptoms needing identification. UMass Extension has a simple scouting form for common greenhouse insect pests. Yellow sticky cards are handy monitoring tools, but they require getting familiar with what gets stuck on them; see guidance like this from NC State Univ. There are many biological control options for tunnels and greenhouses. These should be preordered in many cases. You can store ladybugs in a fridge if you have a history of aphid problems.

18. **Install sensors and alarms**. An air temperature alarm and an emergency heater are basic examples of this, but there are many more options for monitors, which should be associated with backup systems or plans in the event of a system failure. Sensors to consider for tunnels are air temperature, soil temperature, relative humidity, irrigation water tank temperature, water pressure, electric voltage, door open/close, carbon monoxide, propane tank level and more. For more info on remote monitoring see the UVM Ag Engineering blog post.



19. **Minimize 'edge effect' yield losses**. Reduced growth of crops in beds or rows along tunnel edges is common and can be due to several factors. Cold water infiltration occurs if the tunnel wasn't elevated above the surrounding ground. To avoid this, the tunnel should be built on an 8 to 12-inch elevated pad. Excavate a 12-foot wide 6 to 8-inch-deep swale along the length and use the excavated topsoil on top of the tunnel footprint. Rains and snow melt runs off into the swale rather than under the baseboard and into the tunnel. Cold air infiltration from outside soil can be reduced with rigid perimeter insulation placed in the ground 12 to 18 inches deep (be careful not to loosen ground posts). HAF fans can prevent pockets of cold air at tunnel edges (see above). Avoid uneven distribution of nutrients, especially when spreading bulk materials like compost. And be aware of less attention to and care of outside rows simply because it's often harder to work along the edges of the tunnel. Whatever the reasons, the total loss of yield along both tunnel edges over time can be significant, so try to avoid the possible causes.



20. **Prepare for rodent control** (they can move in fast). Options includes active measures like traps, rodenticides, cats, etc.) and passive measures like sealing doors, packing up produce, hardware cloth for exclusion, accepting the loss, selling everything early. For more info on these options see a detailed post on the UVM Ag. Engineering blog.

21. **Enhance labor efficiency**. Take a step back and consider ways to perform tasks more efficiently. Start with tasks that require a lot of time. How long would it take for a flat filler to pay back? How much walking could be avoided when harvesting with the use of carts, or a trolley conveyor? Do you have written standard operating procedures, or SOPs, to support workers in performing time-consuming tasks efficiently? Check out this overview of ways to lower greenhouse labor costs by, you guessed it, John Bartok. The short section on workstation design for repetitive tasks is worth a read for most growers.

22. **Set up systems to track what you want to improve**. As Yogi Berra once said, if you don't know where you're going, you'll probably get there. Want to improve the yield of a crop, or the amount of time spent on certain tasks? You'll need to have a baseline. Weighing all harvests and timing all tasks is unrealistic, so start with the most important crops and tasks, and set up a simple way to measure them. It could be by counting boxes or other units of harvest over time, perhaps from one representative area of a tunnel. How will data be recorded? Maybe old-fashioned clipboards with harvest tally forms, or dry-erase boards, or iPads with spreadsheets. Set up a system that works for your farm.

Bonus points: Take time to celebrate. The world's a crazy place and you and your team are doing good by growing plants that help people stay healthy in body and spirit! It's important to acknowledge this meaningful work--however you choose to do that.

1/7/22